

The Development of a National Science, Mathematics, Engineering and Technology Education Digital Library: Lessons Learned from Needs

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Abstract: The emergence of the World Wide Web (WWW) in the early 1990's as a viable means for national and international sharing and re-use of education materials fundamentally changed our view of the way education and learning can be delivered. Internet-mediated learning environments provide mechanisms for the learner to be *anyone, anywhere, at anytime*. But while educators are developing an enormous quantity of materials for use through the Web, potential users face a daunting challenge when it comes to locating them, evaluating their quality and using them effectively. Understanding and overcoming this challenge is crucial if we are to fully exploit the opportunity to improve learning that these new resources have created

We are leading the development of an alliance to develop a National Science, Mathematics, Engineering and Technology Education (SMETE) Digital Library at www.smete.org. This *digital learning community* will provide access to a variety of digital learning resources and services from a federation of partners. It will serve a community of learners and instructors across the full range of SMETE disciplines and serve users from K-12 to undergraduates to life-long learners.

Keywords: digital library, technology enhanced teaching and learning, SMETE,

1.0 Introduction

The World Wide Web and networked information technologies provide this us with an unprecedented opportunity to develop a comprehensive infrastructure to support and facilitate educational initiatives in science, mathematics, engineering and technology (SMET). Internet-mediated learning environments provide mechanisms for the learner to be *anyone, anywhere, at anytime*. But while educators are developing an enormous quantity of materials for use through the Web, potential users face a daunting challenge when it comes to locating them, evaluating their quality and using them effectively. Understanding and overcoming this challenge is crucial if we are to fully exploit the opportunity to improve learning that these new resources have created [1].

In response to these problems, two key National Science Foundation (NSF) reports, “Systemic Engineering Education Reform: An Action Agenda” [2] and “Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology” [3], urge the formation of a national resource to provide access to quality learning objects and to disseminate successful educational practices in science, mathematics, engineering and technology education (SMETE).

This broad vision of this national resource, a *digital learning community* for educators and learners, requires an integrated, multi-disciplinary view of science, mathematics, engineering and technology education. Since the early 1990's, NEEDS—The National Engineering Education Delivery System (see www.needs.org) has provided this vision for the engineering education community. NEEDS and its alliance partners are taking the lead in developing a comprehensive resource for SMET education at www.smete.org. This national resource has often been described as a ‘digital library.’ We believe our vision goes beyond the traditional academic library in digital form [4]. We envision this national resource serving a community of learners in science, mathematics, engineering and technology education that encompasses faculty, students and life-long learners. We see community members interacting with one another to develop, locate, use and recommend to each other resources to enhance learning. We refer to this national resource as a *digital learning community*, where community members, both novices and experts in technology enhanced learning, work together to improve science, mathematics, engineering and technology education in their classrooms, in their coursework, across disciplines and with each other [5].

This paper will articulate an evolving community vision for the development of a national digital library for SMETE. It will address the development of vital services and user studies and highlight “lessons learned” from NEEDS. Finally we will outline some of the key open issues in developing a national digital library for SMETE.

2.0 Background on NEEDS

NEEDS provides a resource where both instructors and learners can search, access, and download digital learning resources over the World Wide Web in science, mathematics, engineering and technology. NEEDS grew out of Synthesis: A National Engineering Education Coalition's determination to share and reuse the instructional technologies developed in support of the coalition's curricular goals [4, 6].

NEEDS has evolved with changes in technology; from its debut in the early 1990's as a "text-based search engine over a centralized library catalog with pointers to digital course material" accessible via telnet [7] to its transition to the Web in 1994 to the current system NEEDS continues to provide its users with the services to meet their needs. NEEDS has developed and implemented key elements in a reliable, distributed, scalable system architecture, including: redundant Web servers; an integrated database with WWW-based searching and downloading, utilizing state-of-the-art database and information technologies; and an indirection system to support multiple, nationally-distributed archive servers for courseware download [4, 6].

NEEDS is expanding its services to include more user-centered support mechanisms, such as "Amazon.com"-like user comments and reviews. The services and features under development are designed to allow NEEDS to continue to meet the needs of diverse user groups—some may use it to locate resources, others may use it to find like-minded educational innovators, while still others may simply want to get a glimpse of how to integrate technology and learning. NEEDS also supports a multi-tier evaluation system [8–10] including a national award competition—the *Premier Award for Excellence in Engineering Education Courseware*.

3.0 Developing a National SMETE Digital Library

Since 1996 the National Science Foundation has studied the development of a national digital library for science, mathematics, engineering and technology education. With the recent program announcement of the National SMETE Digital Library program in 2000 [11] and preliminary funding under the Digital Libraries Initiative-Phase 2, NSF has begun to develop this national resource. This program is envisioned as a federation of services and collections that function together to provide *seamless* access to the wealth of teaching and learning materials under development. Most importantly it will be driven by, facilitate and promote change in SMET educational innovations. From its debut as the 'Library of Undergraduate Science Education (LIBUSE)' concept in 1996 to the NSDL program of today, NEEDS has provided leadership in the development of this national resource for the community of learners in SMETE [12–14].

NEEDS is leading the development of an alliance to build the National SMETE Digital Library (NSDL) at www.smete.org. The alliance is a web of partnerships encompassing disciplinary collections, researchers, commercial and non-profit education organizations, and industry. Our vision for the national digital library for science, mathematics, engineering, and technology education is one of a diverse and dynamic learning community. Our goal is to establish a national digital library for SMETE that is much more than a static information repository. The alliance intends to create a dynamic learning community that promotes and supports SMET education in the 21st century by providing a broad and deep infrastructure of disciplines, collections, services and targeted research to serve a community of learners in science, mathematics, engineering and technology education. The NSDL must be a place where members of the community of learners interact with one another to develop, locate, use and discuss digital resources that enhance teaching and learning. The SMETE community needs services and resources to support both novices and experts in technology-enhanced learning in their classrooms, in their coursework, across disciplines and with each other.

3.1 Multidisciplinary Partnerships

Our background in engineering education (through NEEDS and the Synthesis Coalition) has shown the value in developing multi-disciplinary teams and strong partnerships among diverse organizations. We are leading the development of an alliance that will demonstrate a federation of collection and service providers in a National SMETE Digital Library at www.smete.org. Ultimately a wide variety of partners will be necessary; some will provide access to collections while others will provide services or the core infrastructure about which the federation is developed. Additionally a breadth and depth of partners is necessary to provide the rich user experience envisioned for the national digital library for SMETE. Alliance partners, such as the Math Forum (see www.mathforum.com) and the Eisenhower National Clearinghouse for Science and Mathematics (see www.enc.org), are working within their own communities to determine the services and features necessary to provide value to their users. The challenge will be bringing these partners together to determine core services and features common to the National SMETE Digital Library. In addition we must plan for identifying and adding additional partners to support the broad reach of the sciences, mathematics, engineering and technology.

3.2 Standards and Protocols for Resource Description and Interoperability

Building upon our experience with NEEDS, we know that standards and protocols are the glue that will allow us to build a *seamless* National SMETE Digital Library at www.needs.org. Standards will provide mechanisms for sharing metadata about resources, and protocols will provide the means to accomplish interoperability between federated systems. The Institute for Electrical and Electronics Engineers (IEEE) is in the process of working with the community-at-large to develop standards for learning technologies in Working Group P.1484 (see ltsc.ieee.org). Also, the digital library research community and general library communities have developed standards for interoperability that we can adopt or adapt to suit the needs of a national digital library for SMETE.

From its inception NEEDS has placed a high degree of importance on standards. In October 1991, NEEDS convened a standards advisory group to examine and recommend existing and developing standards for describing resources in a networked environment in order to allow access to all users [15–16]. From the use of the USMARC standard for the bibliographic cataloging of our resources [16] to the adoption of emerging learning object metadata standards of today –the IMS Metadata Specification version 1.0 and the proposed IEEE Learning Object Metadata standard [17–18]–NEEDS has been at the forefront in describing networked learning resources.

To accomplish the interoperability required of a federation of collection and service providers, we can look to the work being developed by digital library researchers and apply it to the SMETE domain. The Dienst and Waters protocols are in use today in the Networked Computer Science Technical Report Library (see www.ncstrl.org). The Networked Digital Library of Theses and Dissertations (see www.ndltd.org) in Computer Science is also experimenting with protocols to perform federated searches over its distributed collection [19]. Researchers at Stanford University are developing a Simple Digital Library Interoperability Protocol (SDLIP) in use locally within their digital library and in conjunction with the digital library research project at the University of California at Berkeley [20–22]. These three examples combined with standards such as Z39.50 and the use of extensible markup language to encapsulate searches [23] are some of the areas we will be exploring as we develop specifications for interoperability in the National SMETE Digital Library [5].

Current standards efforts IEEE Learning Object Metadata Working Group P1484.12 (see ltsc.ieee.org/wg12), and the work of various international groups such as IMS (see www.imsproject.org) and ARIADNE (see ariadne.unil.ch), have focused on describing the content of the learning resource. NEEDS is in the process of adopting these emerging standards and continues to follow their development. We are committed to implementing and participating in the development of standards and specifications for metadata and content description. We feel it is important to be a key player in the development of these items, we bring ten years of experience in running a production system that takes advantage of these standards and specifications [5].

3.3 Community of Learners

If standards and protocols are the glue that holds the technical infrastructure in place, then community provides the threads to weave content and pedagogy into learning and teaching. We know that for any effort to be successful, the resources we develop for a national digital library for SMETE, must be built around and support a community of use and practice. Thus the *digital learning community* of the National SMETE Digital Library at www.smete.org, to reflect some of the best qualities of real life communities, should be persistently interactive, mutually supportive, and provide its members with mechanisms to adapt and build on the work of others to strengthen SMET educational programs [1].

The long-term vision of our community building efforts is to facilitate users searching for both content as well as educational concepts (e.g., geometry or problem-based learning). We also want to help users answer the question, “How do I use these learning resources once I’ve found them?” This evolution to support communities of learners emphasizes interactivity, user-to-user communication and community building. Two steps we have already initiated are allowing users to post reviews (i.e., “Amazon.com”-like reviews) and participate in focused discussion groups (e.g., freshman design). It may be possible, however, to go further; we envision “pedagogical metadata” that better encapsulates or packages the pedagogical applications of a learning resource [5].

3.4 Towards the Future

As we look toward the future, we see the growing need for work to be done in several key areas. We see the need to continue to develop disciplinary and cross-disciplinary subject thesauri to better describe learning resources. These subject hierarchies will allow the user to both browse for learning resources he/she may be looking for as well as assist searchers in finding related materials (greatly improving discoverability of resources). Groups such as the American Mathematics Metadata Task Force (see www.ammtf.org), and some of our early efforts with NEEDS in engineering, already have initiated development of discipline-based subject hierarchies.

We also see the need to develop taxonomies to better encapsulate the context in which a learning resource is used. Finding the materials is only a small part of the challenge facing educators and learners today; knowing what to do with the materials poses the tougher challenges. Current collection providers have provided the first part of the needed solution—tagging the basic description of the content and technical requirements of the resource. In some cases, for example by the Math Forum and NEEDS, collection providers have taken initial steps in describing the much-needed part that of pedagogical application of the resource. However, current efforts in metadata tend to provide only a macro-level view of the pedagogical application of a learning resource. What's needed is a micro-level, or more granular, view of how to use a particular resource. We envision collection providers continuing to provide the basic tagging of the content of a resource. However, we also see them working to develop an author/instructor completed “short form” that describes the pedagogical application of a resource. From this “short form” we envision being able to extract a much richer set of descriptions about possible applications of the learning object. This “short form” combined with culling discussions about resources we feel will ultimately allow us to provide a better description of the context in which to use learning objects [5].

4.0 Summary

The frenetic pace of change in information technologies has exacerbated the age-old problem of finding information. With everyone a “publisher” in this new information age, the volume of materials is drastically increasing. Even if we “just” limit ourselves to engineering education, the volume is enormous. NEEDS and alliance partners are developing a new vision, a *digital learning community* that extends beyond a single discipline. We are working to develop a National SMETE Digital Library at www.smete.org; encompassing a federation of collection and service providers to support the learning and teaching needs of a broad community of learners in the sciences, mathematics, engineering and technology education.

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